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INNOVATIVE TECHNOLOGY
Summary Report

Pulsed-Air Mixer

Tanks Focus Area

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Office of Science and Technology

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INNOVATIVE TECHNOLOGY

Summary Report

Pulsed-Air Mixer

OST Reference #1510

Tanks Focus Area

Demonstrated at
Hanford Site
Richland, Washington
and
Oak Ridge National Laboratory
Oak Ridge, Tennessee

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

Technology Summary

Millions of gallons of radioactive waste reside in underground storage tanks at U.S. Department of Energy (DOE) sites. The production of atomic weapons generated the tank waste found throughout the DOE complex. The waste will be removed from the tanks, transferred to holding tanks, immobilized, and stored to prevent release to the environment. Various waste retrieval and processing methods are being evaluated to deal with the wide range of consistencies in tank waste.

The pulsed-air mixing technique uses discrete pulses of air or inert gas to produce large bubbles near the tank floor, which induce mixing as they rise to the surface of the liquid. An array of horizontal, circular plates is positioned a few centimeters from the tank floor. Pipes supply pulses of gas to the underside of each plate. Control equipment and gas-pulsing valves are used to control pulse frequency and duration, gas pressure, and plate sequencing to create optimal mixing conditions within the tank. In this report, the phrase "pulsed-air mixing" refers exclusively to the mixing technology provided by Pulsair Systems, Inc. Figure 1 depicts the pulsed-air mixer demonstrated in a simulant holding tank at Oak Ridge National Laboratory (ORNL).

Figure 1. A pulsed-air mixer in action at the ORNL Gunite and Associated Tanks simulant tank. (Accumulator plate is roughly 1.5 m from the far end of the tank and 1 m from the tank wall on the left side of the photo).

When applicable, pulsed-air mixing has numerous advantages over other waste mixing approaches (e.g., jet mixer pumps): reduced equipment cost, reduced risk of equipment failure, easier equipment decontamination, very low operating costs and power requirements, no minimum liquid level required for operation, and minimal heat addition to the waste. Pulsed-air mixers require no moving mechanical parts within the tank. Mixer pumps, by contrast, have shaft seals, impellers, and motors. Failure of any of these components could necessitate removal and replacement of the mixer pump.

Pulsed-air mixing is applicable to a variety of mixing challenges at the DOE waste sites. The financial and operational advantages of pulsed-air mixing make this technology a viable tool for many waste mixing needs. Several specific applications for pulsed-air mixing are as follows:

- Mixing in ORNL Tank W-9, which is the waste receiver tank for the Gunite and Associated Tanks (GAAT) remediation project. The mixer system is installed.

- Mobilization and mixing of sludge waste in selected Idaho National Engineering and Environmental Laboratory (INEEL) V-tanks. A pulsed-air mixer deployment concept for the V-tanks has already been developed.

- Mixing low solids–content salt liquors such as those in the Hanford low-level waste vendor feed tanks. A scale-up analysis is under way to predict mixing times for this application.

- New processing or storage tanks. Installation of pulsed-air mixers during tank construction is inexpensive, and a sufficient number of accumulator plates to ensure adequate mixing can be easily installed.

- Mixing grout with waste heels from tank closure. Although this application of pulsed-air mixing has not yet been demonstrated, testing indicates that the use of pulsed-air mixing technology to mix dry cementitious solids with water in a horizontal, cylindrical tank is feasible. It is recommended that some larger-scale, tank-specific testing be performed prior to actual application.

In general, the pulsed-air mixing technology applies to mixing applications without the requirements to mobilize stiff, cohesive sludge or maintain large particles in suspension.

Demonstration Summary

Hanford Site demonstrations:

- 1/12-scale mock-up of a Hanford double-shell tank (DST), FY95—The pulsed-air mixing action was shown to sufficiently maintain solids in suspension, but the mixing action was not enough to mobilize cohesive sludge from the tank floor using a 13-plate mixing array. The data implied that a large number of accumulator plates would be required to mobilize more than 90% of the sludge in a full-scale (22.9-m-[75-ft-]diameter) Hanford DST.

- 1/12-scale mock-up of a Hanford DST, FY96—This test revealed that the fluid velocities produced by the rapidly expanding gas bubbles near the tank floor are sufficient to stir up cohesive tank sludge, but to only a limited distance from the plate. Investigations also established correlation between the bubble pulse radius (R_{pulse}) and accumulator plate diameter, gas pressure, and gas line diameter.

- 1/4-scale mock-up of a Hanford DST, FY96—The key finding of this test was that the slurry mixing performance of the pulsed-air mixer was better than expected. Using a pulsed-air mixer for slurry mixing requires fewer plates than mobilizing cohesive sludge. A single, centrally located accumulator plate in the 1/4-scale tank maintained approximately 80 wt % of the solids in suspension, demonstrating that large-scale circulation patterns induced in the slurry by the rising bubbles can effectively maintain solids in suspension.

ORNL demonstrations:

- Simulant holding tank, FY97—A single pulsed-air accumulator plate was used to remix the settled waste simulant used for confined sluicing end effector retrieval testing as part of the GAAT remediation project. Moving the plate to various locations within the tank enabled the majority of the settled solids to be resuspended and transferred back to the GAAT retrieval test bed. This mixer demonstration was witnessed by key staff on the GAAT remediation project, who subsequently indicated a strong interest in using a pulsed-air mixer for slurry suspension in GAAT W-9.

- GAAT W-9, FY98—Pulsed-air mixing was first operated in June 1998. The system will continue to be used in W-9 through FY00 and possibly into FY01. The mixer is installed to maintain the solids concentration at up to 10 wt % solids and to settle out particles larger than 100 micrometers prior to transfer to the Melton Valley Storage Tanks (MVSTs).

Pacific Northwest National Laboratory (PNNL) and Pulsair Systems, Inc. of Bellevue, Washington have been working together with the Applied Physics Laboratory at the University of Washington to develop the pulsed-air mixer and its potential application at many DOE sites.

Two tank-specific issues must be addressed before pulsed-air systems can be installed in a specific radioactive waste tank:

- When the accumulator plates are operated at a pressure sufficient to generate bubbles (e.g., up to 100 psig), a shock wave can be produced within the waste. The effect of the shock on tank integrity must be examined.

- A fine mist of waste slurry is formed when large bubbles break the waste surface. This aerosol generation is primarily an operating-cost issue (i.e., a higher aerosol-generation rate requires that the tank ventilation system be designed with greater aerosol-handling capability).

Pulsed-air mixing is commercially available from Pulsair Systems, Inc., and it is used extensively in the lubricant-oil mixing industry, municipal wastewater treatment plants, and other applications. No future demonstrations are planned for pulsed-air mixing. The technology is ready for implementation.

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Other

All published Innovative Technology Summary Reports are available at http://ost.em.doe.gov. The Technology Management System, also available through the EM-50 Web site, provides information about OST programs, technologies, and problems. The OST reference number for pulsed-air mixing is #1510.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

Pulsed-air mixing equipment has been applied to a number of mixing applications in the chemical processing industry. This technology was demonstrated to evaluate if pulsed-air mixers might meet the slurry mixing needs of DOE and to develop operational parameters to help determine deployment options for potential sites.

The pulsed-air mixing technique uses discrete pulses of air or inert gas to produce large bubbles near the tank floor. The bubbles induce mixing as they rise to the surface of the liquid. An array of horizontal, circular plates is positioned a few centimeters from the tank floor. Pipes supply pulses of gas to the underside of each plate. Control equipment and gas-pulsing valves are used to control pulse frequency and duration, gas pressure, and plate sequencing to create optimal mixing conditions within the tank. Figure 2 shows a pulsed-air mixer installed in a demonstration tank at the Hanford Site.

Figure 2. Pulsed-air mixing array in 1/12-scale tank (FY95) .

Figure 3 shows the growth of a pulsed-air bubble. When compressed air is supplied to the underside of the accumulator plate, the growing bubble expels liquid outward from under the plate. This stage is shown in the upper left sketch in Figure 3. Bubble growth continues outward beyond the edge of the accumulator plate to a distance of R_{pulse} from the plate center. The air/liquid interface reaches R_{pulse} quickly; stop-action video reveals that R_{pulse} is reached about 0.1 sec after pulse initiation. After this point, the bubble collapses radially inward and moves up toward the liquid surface.

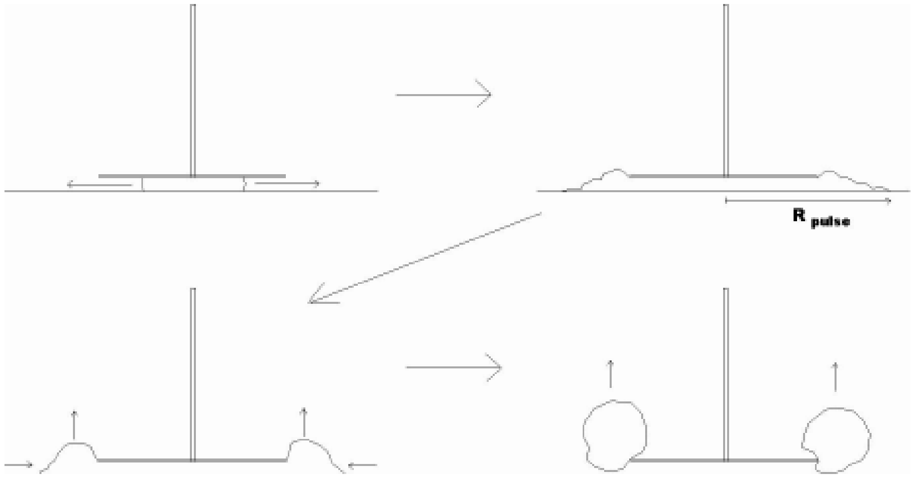

Figure 3. Sketch of gas bubble growth showing R_{pulse}.

For slurry mixing, both the rapid growth of the bubble to R_{pulse} and its subsequent rise to the liquid surface are relevant. The fluid velocities produced by the rapid radial growth of the bubble are high enough to sweep settled solids off the tank floor. The rising bubble induces large-scale fluid circulation patterns within the tank that maintain slurry uniformity and keep solids in suspension. The circulation pattern generated by bubbles from a centrally located plate is shown schematically in Figure 4.

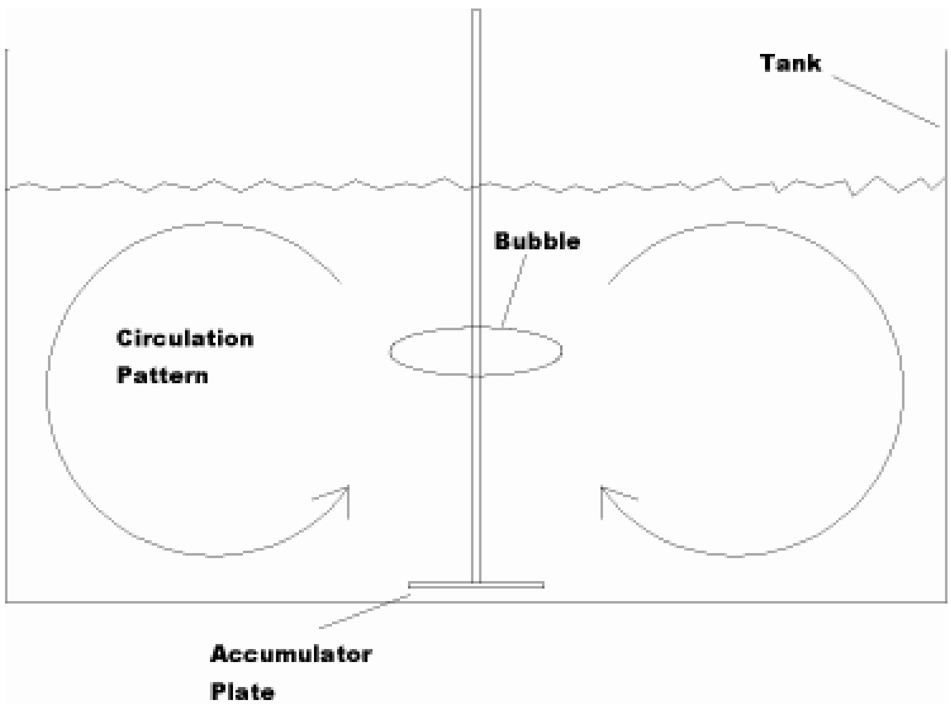

Figure 4. Bubble-induced fluid circulation pattern.

The main advantages of pulsed-air mixers are simplicity and the absence of moving parts within the waste tank. The equipment is highly reliable, safe to operate, and economical. The mixer hardware can be installed through a small-diameter tank riser and removed after weeks of operation in a poorly characterized mixture. Essential equipment included in this technology is as follows:

- Pulsair accumulator plate assemblies (generally double plates separated vertically),
- pneumatic supply lines to accumulator plates,
- a Pulsair control unit with a separate injection valve on each line, and

- high-pressure gas and reservoir tanks to operate the pulsed-air mixer at pressures up to 100 psig.

Pulsed-air mixing is applicable to mixing applications that do not require stiff, cohesive sludge to be mobilized or large particles to be maintained in suspension. In some instances, pulsed-air mixing can be used for sludge mobilization and mixing large particles, but the tank geometry allow the development of large-scale fluid circulation patterns. Favorable tank geometry is sloping tank walls to direct sludge and settling particles into the effective reach of the accumulator plates. Horizontal cylindrical tanks (e.g., INEEL V-tanks, ORNL MVSTs, and ORNL Bethel Valley evaporator service tanks) have favorable geometries for pulsed-air mixing. Pulsed-air mixers also easily mix cone-bottomed tanks. Large-diameter, flat-bottomed tanks such as the Hanford double- and single-shell tanks are less favorable for pulsed-air mixing applications. Pulsed-air mixers can still be employed in these tank geometries, but the mixing is less efficient and more particle settling may occur.

System Operation

Special Operational Parameters

Tanks must be ventilated because of aerosol generation. Before a pulsed-air mixer can be deployed in a tank, the ventilation system must be analyzed to ensure that aerosol-handling capabilities are adequate.

Material, Energy, and Other Expendable Items

Accumulator plates in various sizes, the plate support structure, and control equipment are required. Pulsair Systems, Inc. can provide control equipment to regulate pulse frequency, pulse duration, plate sequencing, and gas pressure.

Maximum air pressure of 100 psig is required. A commercially available 80-gal air tank acts as a reservoir to supply compressed air to the accumulator plates.

Personnel Requirements

Very little supervision is required to operate the mixer after its installation. One to three personnel would be expected to supervise operations, depending on site requirements.

Secondary Waste Streams

Aerosol generation should be addressed prior to deployment. Oak Ridge National Laboratory addressed this concern for GAAT W-9 by using a surplus high-efficiency particulate air filter system and the central ventilation system for the GAAT South Tank Farm. These engineering controls were provided with minimal costs.

Special Operational Concerns and Risks

Pressurized 80-gal air tanks supply the plates to provide a sharper pulse. There is a low potential for air-tank failure.

Injection valves may stick. An orifice above the 80-gal tanks was designed to limit the volumetric flow of air. The overflow rate is calculated to maintain a negative pressure on the system should a valve stick open.

SECTION 3

PERFORMANCE

Demonstration Plan

Demonstration testing was carried out at PNNL in FY95 and FY96. The PNNL demonstrations were designed to meet the following objectives:

- Evaluate whether the mixing performance expected from pulsed-air mixers would fulfill Hanford's slurry mixing needs.
- Determine whether pulsed-air mixing could maintain waste particles in suspension.
- Evaluate the ability of pulsed-air mixing to resuspend the sludge known to have accumulated in many Hanford DSTs.
- Quantify the fluid velocities produced near the tank floor by pulsed-air accumulator plates, and correlate the peak fluid velocities with mixer design and operation parameters.

Results

In FY95, pulsed-air mixing tests were conducted in a 1/12-scale tank (based on Hanford tank dimensions). The testing confirmed the ability of pulsed-air mixers to maintain solids in suspension. The issue of pulsed-air mixing scale-up was addressed in the FY96 tests conducted in both 1/12- and 1/4-scale tanks. The key findings of the testing are as follows:

- A single, centrally located mixing plate in the 1/4-scale (18.75-ft-diameter) tank can maintain approximately 80 wt % of the solids in suspension.
- The fluid velocities produced by the rapidly expanding gas bubble near the tank floor are sufficient to stir up cohesive tank sludge. The sludge is mobilized by the pulsed-air bubble out to a distance from the center of the plate that is characterized by R_{pulse}. Beyond R_{pulse}, the fluid velocity rapidly declines. Thus, pulsed-air mixers are designed such that the plates are greater than or equal to 2 R_{pulse} apart.
- R_{pulse} increases with mixing plate diameter, gas pressure, gas line diameter, and plate standoff distance. The increase in R_{pulse} with gas pressure is roughly linear up to certain pressure. Plate standoff distance has little effect on R_{pulse} provided the standoff distance is greater than a minimum value (h_{min}), which is based solely on the size of pipe used to deliver compressed air to the mixing plate. Mixer installation logistics and the capacity of the compressed air supply determine the mixer plate diameter, gas pressure, and the maximum practical gas line diameter.
- The large number of plates required to cover the floor of a large-diameter tank can present a challenge for pulsed-air mixing applications. At Hanford, it was predicted that more than 500 mixing plates would need to be distributed on the DST floors and operated at 100 psig to mobilize all the sludge.
- Sludge mobilization is more feasible in tanks without large diameters (e.g., INEEL V-tanks and MVSTs). For example, the sludge in the INEEL V-tanks can be resuspended by deploying only four mixing plates along the tank bottom.

The data from PNNL tests were used to design a pulsed-air mixing system for Oak Ridge. The pulsed-air mixing system was delivered to ORNL in March/April 1998, where it underwent a series of cold tests at the Robotics and Process Systems Complex to verify system integrity, confirm functionality of accumulator plate arm deployment, and demonstrate installation and retraction through a simulated tank riser. Installation procedures were also finalized and validated during cold testing, and removal options were evaluated. Following successful cold testing, the pulsed-air mixer was relocated to GAAT W-9.

The pulsed-air mixing assemblies were installed in GAAT W-9 in June 1998. The system used at GAAT consists of three in-tank mixing assemblies, controller, air supply, and tank interface hardware. Mixer and controls were manufactured by Pulsair Systems, Inc.; the in-tank hardware and tank interface were manufactured by University of Washington Applied Physics Laboratory under contract to PNNL. The air supply was designed and installed by ORNL. The mixing assemblies include three or four accumulator plates located at the ends of folding arms. The arms also function to convey air from the air compressor to the accumulator plates. The mixing assemblies are deployed at predetermined locations along the bottom of the tank.

Proper operation of the system was confirmed during a brief “hot” test, during which aggressive mixing of the tank contents was achieved. Further operation of the Pulsair mixing system in GAAT W-9 was delayed until late in the year pending approval of the required safety documentation covering system operation in conjunction with the newly installed Solids Monitoring Test Loop (SMTL). The SMTL contains in-line solids-monitoring instrumentation with the capability of providing real-time solids data for a stream of GAAT W-9 mixed slurry.

Pulsed-air system testing in GAAT W-9 resumed in December 1998. The system was initially operated for several hours, and a supernatant sample was extracted from the tank. Analysis of the sample indicated that the radionuclide content was within the safety limit established for SMTL. The supernatant was also analyzed for density and solids content. Suspended solids content, a good indicator of mixer performance, was found to be approximately 2.5 wt %, compared to a premixed suspended solids baseline of less than 0.1 wt %. (The target is 5–10 wt %.)

During this initial operation, one of the thirteen accumulator plates was found to be clogged with sludge. This accumulator plate was located directly beneath the inlet for slurry from other GAAT tanks being consolidated into GAAT W-9. Applying approximately 200-psi hydrostatic pressure with a small hand pump cleared the plate. It was determined that this clog was the result of the extended period of mixer inactivity since initial installation. To avoid future blockage problems between mixing campaigns, the system will be operated periodically to keep the accumulator plates free of sludge.

During January–March 1999, pulsed-air mixing was operated periodically to provide qualitative and quantitative data as to mixer performance and capabilities. The suspended solids content achieved was 2.4–5.3 wt %. Additional testing is planned for upcoming months. To ensure the overall vacuum condition in GAAT W-9 is maintained during testing, an auxiliary high-efficiency particulate air (HEPA) system is being prepared for use with mixer operations.

Based on operations to date, pulsed-air mixing appears capable of achieving the target 5 wt % solids content necessary for transfer of the mixed slurry to the MVSTs. Additional testing will be performed to evaluate sludge distribution in GAAT W-9 following initial supernatant transfers. The ability of pulsed-air mixing to maintain near-target solids content following removal of the sludge fraction in the first slurry batch(es) to the MVSTs will continue to be evaluated.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Pulsed-air mixing must be considered on a tank specific basis. Two competing technologies are discussed below.

Mechanical Mixer Pumps
The current baseline approach for sludge mobilization is a mechanical mixer pump, a submersible pump that produces liquid jets parallel to the tank floor that mobilize sludge and mixes the resultant slurry. Mixer pumps have been used at both the Hanford and Savannah River sites.

Mixer pumps

- are expensive to purchase and install,
- add heat to the tank waste,
- have a limited operating lifetime,
- may require frequent maintenance, and
- are difficult to retrieve from tanks.

Waste Transfer Pumps
Previous engineering studies at the Hanford Site considered sluicing and recirculation of the sluice water with a transfer pump. In general, sluicing was found to drastically increase the waste volume because of excess dilution. Tank mobilization by recirculation of the waste through the transfer pump reduces dilution water requirements.

Technology Applicability

Pulsed-air mixing equipment has been applied to a number of difficult mixing applications in the chemical processing industry. However, most previous applications involved mixing of particle-free fluids. Pulsed-air mixing is currently used extensively in the lubricant oil–mixing industry, municipal wastewater treatment

Patents/Commercialization/Sponsors

The work performed to demonstrate this technology relies on the mixing technology available from Pulsair Systems, Inc. Pulsair Systems, Inc. has patents in pulsed-air mixing technology.

In fiscal year 1995, a study of pulsed-air mixing for application at Hanford was conducted by Pacific Northwest National Laboratory. This study was funded by EM-30 through Westinghouse Hanford Company. Continued research from FY97 through FY99 was funded through the Tanks Focus Area. The installation in GAAT W-9 was cofunded by Oak Ridge National Laboratory.

SECTION 5

COST

Methodology

The goal of the GAAT W-9 application was to mobilize small-diameter (up to 100-micrometer) solids for the transfer through a mile-long waste transfer line. For this application, the pulsed-air mixer needed to mobilize only enough solids to meet the desired limit of up to 10 wt % solids.

The system used at GAAT consists of three in-tank mixing assemblies, controller, air supply, and tank interface hardware. The mixing assemblies include three or four accumulator plates located at the ends of folding arms. The arms also function to convey air from the air compressor to the accumulator plates. The mixing assemblies were deployed at predetermined locations along the bottom of the tank.

For comparison purposes, the alternative technology is assumed to be a 600-hp mechanical mixer pump; however, the mechanical mixer pump is not optimum for this application. Typically, mechanical mixer pumps are deployed to clean out the entire tank contents. Hence, mechanical mixer pump operation in GAAT W-9 would be intermittent so that only a fraction of the tank contents would be mobilized. If the pulsed-air mixer had been designed to remove most of the tank contents (which was not desired for this application), the performance of the mixer would need to be enhanced by increasing the number or diameter of the individual plates, the pulse frequency, or possibly the airflow.

Cost Analysis

Table 1 compares capital, operating, and maintenance costs for the mechanical mixer pump to those for the pulsed-air mixer. This comparison is qualitative, as the actual costs will depend on the application and factors such as tank loading restrictions and availability of existing infrastructure.

Table 1. Cost comparison for mechanical mixer pump and pulsed-air mixer

Component	Mechanical mixer pump requirements	Pulsed-air mixer requirements[a]
Equipment	$300K to $500K	~$145K for GAAT assembly and controller
Installation	Requires upgrading tank to bear the weight of the mixer pump or building a superstructure to bear the weight external to the tank	Requires air compressor and a deployment system to distribute the plates inside the tank
Operating	Electrical power plus worker to supervise tank mixing	Compressed air supply plus worker to supervise tank mixing
Maintenance	Replace pump every 2 to 5 years	Minimal costs because no moving parts are inside tank
Disposal	Dispose of old pump every 2 to 5 years	Dispose of system at end of processing
Tank upgrades	May require adding additional risers	May require ventilation system upgrades

[a]The waste heel remaining in GAAT W-9 will be retrieved using another system. This system is not included in the capital costs since only the mixing application is being evaluated.

Capital Costs

Capital costs for a pulsed-air mixer system are estimated to be $100–200K, compared to $300K–500K for a mixer pump. The estimated cost for GAAT W-9 was ~$145K for the mixers and controllers. This cost did not include installation, air compressor, or piping system. A deployment system was also needed for the pulsed-air mixer in GAAT W-9. The deployment system was designed to distribute the plates inside the tank.

Operating and Maintenance Costs

The operating costs for pulsed-air mixing are similar to those for a mechanical mixer pump. Both require one to three workers to supervise the tank mixing, depending on site requirements. The maintenance costs are negligible for pulsed-air mixers because no moving parts contact waste. Mechanical mixer pumps, by contrast, have shaft seals, impellers, and motors potentially submerged in the waste. Failure of any of these components necessitates replacement of the mixer pump. The life cycle of a mechanical mixer pump is two to five years, compared to the life of the project for a pulsed-air mixer.

Technology Scale-Up

The number of injection valves and accumulator plates per tank vary with tank size and application. For the system deployed in GAAT W-9, the zone of influence of each plate is 3–4 ft. For a single accumulator plate, full-scale mixing times on the order of 3 h are predicted for an application where homogenization of miscible liquids is the goal. Mobilization and mixing of settled solids would require significantly longer mixing times, and mixing might not be sufficient to suspend all the solids. Despite the promising results for pulsed-air mixers at GAAT W-9, there are applications where it is not the right choice. For example, pulsed-air mixing is not well suited for the mobilization of stiff, cohesive sludge in large-diameter tanks because of the very large number of accumulator plates that would be required.

Cost-Benefit Analysis

Pulsed-air mixing is expected to be applicable to a variety of mixing challenges at DOE waste sites. The in-tank components for pulsed-air mixing are much simpler and less expensive than mechanical mixing equipment, and the system uses compressed air instead of electrical power. Because of the financial and operational advantages of pulsed-air mixing compared to other mixing approaches, it should be considered for use wherever it can be shown that adequate mixing will be achieved.

Cost Conclusions

Pulsed-air mixing was well suited for the GAAT W-9 application. The pulsed-air mixer deployed in GAAT W-9 was designed to control the solids content of the supernatant prior to transfer to the MVSTs. The technology provided reduced capital and operating costs. Most of the capital cost savings resulted from reducing the need to upgrade tanks to bear the weight of a mixer. For longer-term applications, the technology will result in life-cycle cost savings because pump maintenance and replacement costs are drastically reduced.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

Regulatory/Permitting Issues—Aerosol generation caused by the pulsed-air mixer is a potential permitting issue. ORNL is demonstrating this technology in GAAT W-9, and no new permitting was required.

Secondary Waste Streams Regulatory Considerations—The effect of aerosol generation needs to be evaluated for each site to determine whether extra permits would be required.

CERCLA/RCRA Considerations—This technology is being considered for wastes regulated by the Resource Conservation and Recovery Act (RCRA). Treatment of wastes by this technology is already regulated by Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Human Health and Environment—The pulsed-air mixer technology is fully contained within the tank, so it does not provide further risk to human health or the environment.

Compliance with ARARs—The pulsed-air mixer demonstrates that applicable or relevant and appropriate requirements (ARARs) can be met.

Long-Term Effectiveness—Pulsed-air mixer operation supports permanent treatment and disposal of radioactive waste stored in tanks.

Reduction of Volume—The pulsed-air mixer does not require any additional water to implement the technology. The competing technology (mixer pump) requires additional water for flushing the pumps. While using the pulsed-air mixer does not reduce the volume of waste, it does not increase the volume of waste in the tank through water addition.

Short-Term Effectiveness—The pulsed-air mixer design includes many fail-safe features. Some hypothetical incidents could cause contaminated material inadvertently escaping the tank.

Implementability—Full-scale implementation of the pulsed-air mixer technology is simple and easy. Pulsed-air mixers require no moving mechanical parts within the tank.

Costs—Costs to build and operate the pulsed-air mixer technology are lower than those of the competing technology.

State Acceptance—As pulsed-air mixing was implemented at ORNL, the State of Tennessee recognized it as a viable technology to mobilize and mix sludge in a tank. State acceptance has been very favorable towards this technology.

Community Acceptance—Community acceptance of pulsed-air mixing has been favorable. Public meetings have been conducted to address tank issues at ORNL, and no negative feedback has been received regarding the use of pulsed-air mixing in the tanks.

Safety, Risks, Benefits, and Community Reaction

Worker Safety—Pulsed-air mixing does not directly expose workers to hazardous or radioactive materials. Due to the lack of mechanical parts required for this technology, the pulsed-air mixer is relatively self-operating, reducing the potential risk to workers.

Community Safety—There is no history of accidents with this technology. Future full-scale processes would be required to comply with DOE safety policies and guidelines. It is expected that these processes would be covered by an amendment to an existing Safety Assessment Report.

Potential Environmental Impacts—There is no routine release of contaminants caused by this technology. There are no potential impacts from transportation of equipment, samples, waste, or other materials associated with this technology.

SECTION 7

LESSONS LEARNED

Implementation Considerations

R_{pulse} characterizes the solids suspension performance of pulsed-air plates. The fluid velocities within R_{pulse} of the plate center are high enough to prevent the settling of waste solids and to mobilize soft to moderately strong cohesive sludge. Beyond R_{pulse}, however, the fluid velocities are insufficient to mobilize sludge or to maintain large particles in suspension.

Correlations based on small-scale testing are available for determining R_{pulse} and scaling the pulsed air mixing system to specific applications. Plate size is usually determined by the size that can be deployed through tank risers. Mixing plates are usually located at a distance of 2 R_{pulse} or greater for slurry mobilization. Fewer plates than needed for cohesive sludge mobilization can address slurry-mixing applications with the goal of keeping the solids in suspension.

Technology Limitations and Need for Future Development

Two issues must be addressed before pulsed-air systems can be installed in radioactive waste tanks:

- Shock Wave—When the mixing plates are operated using a relatively high gas pressure (e.g., 100 psig), a considerable shock wave can be produced within the waste. The effect of the shock on the mechanical and structural integrity of the tank must be examined to ensure the tank is not damaged. Operating the mixer at a lower pressure can reduce shock wave intensity but decreases the bubble pulse radius. It may be possible to alleviate much of the shock wave by making small changes to the pulse valve and gas line designs.

- Aerosol Generation—A fine mist of waste slurry is formed when the large bubbles break the waste surface. Whether the rate of aerosol generation is large enough to be of concern is not yet known. This is primarily an operating issue. High aerosol generation rates might require that tank ventilation systems be designed with greater capacity. Pulsed-air aerosol generation rates are expected to be similar those for tank sluicing. If this is the case, it is unlikely that tank ventilation systems would require upgrades.

Despite the encouraging test results for pulsed-air mixing, it is clear that there are applications where pulsed-air mixing is not the best choice. For example, the mobilization of stiff, cohesive sludge in large-diameter, flat-bottomed tanks is not well suited for pulsed-air mixing.

APPENDIX A

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APPENDIX B

LIST OF ACRONYMS

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	Department of Energy
DST	double-shell tank
FY	fiscal year
GAAT	Gunite and Associated Tanks
INEEL	Idaho National Engineering and Environmental Laboratory
MVST	Melton Valley Storage Tank
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
RCRA	Resource Conservation and Recovery Act
SMTL	Solids Monitoring Test Loop